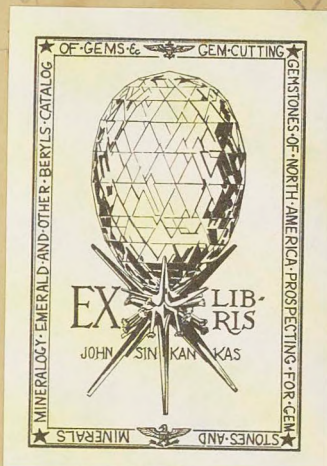


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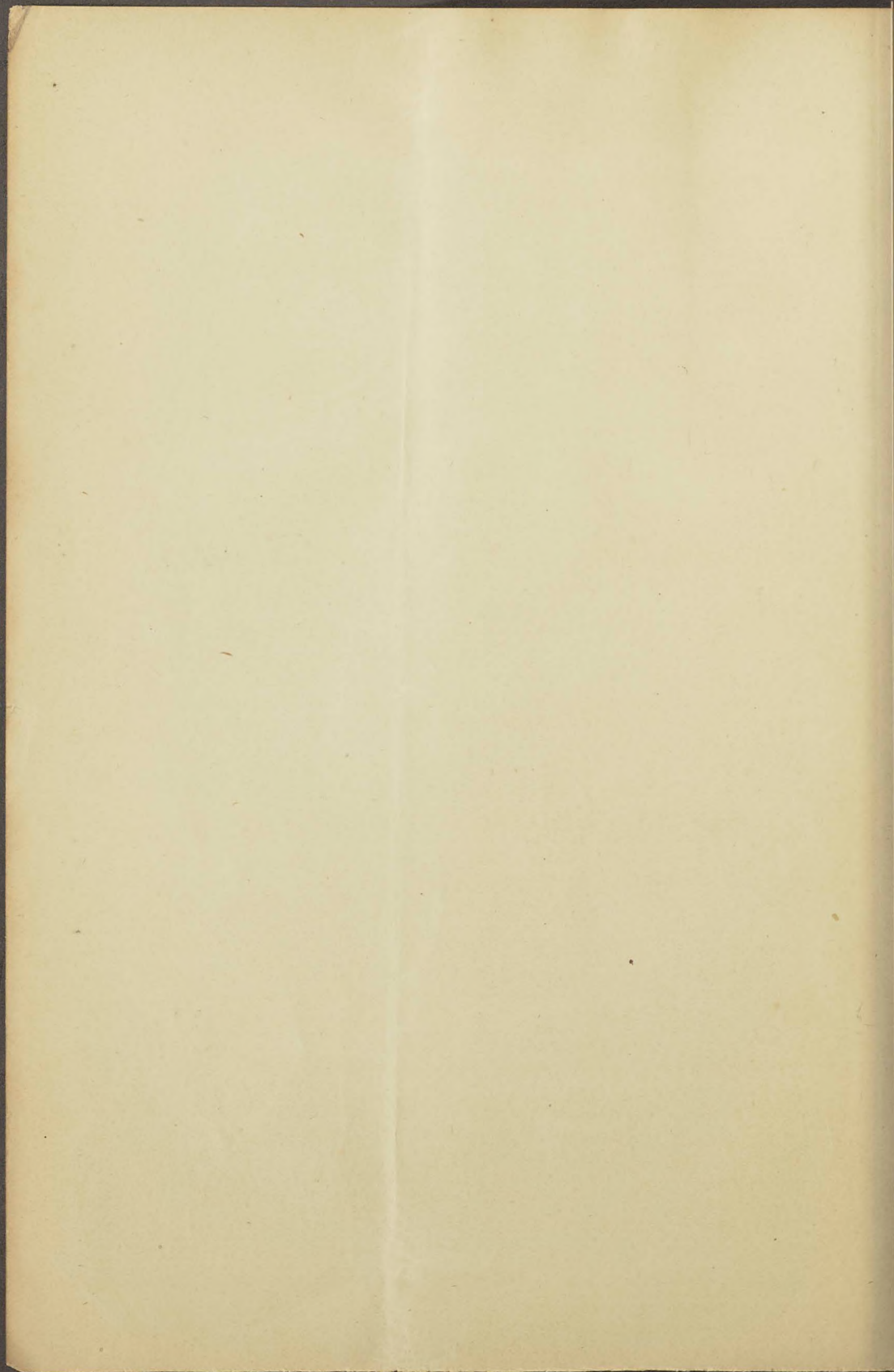


[FROM THE AMERICAN JOURNAL OF SCIENCE AND ARTS, MAY AND JUNE, 1876.]

RESEARCHES ON THE
SOLID CARBON COMPOUNDS IN METEORITES.

By J. LAWRENCE SMITH,
Louisville, Kentucky.

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IN the study of Meteorites, it is well known that, of all the simple and compound substances met with in these bodies, the carbon has received the least study and investigation. This has arisen principally from the limited amount of material at the command of the chemist,—a fact to be regretted, since if any one element more than another demands attention, and excites

wonder at the part it plays, either as an element or in its endless combinations with other substances, that element is carbon.

In its elementary condition we see it in crystals of exceeding hardness and brilliancy in the diamond, and also in irregular, nearly opaque masses that are not to be confounded with the diamond. Again, we have carbon in a soft, black, unctuous state, either in lustrous flaky crystals, or in fine-grained masses. It also occurs in the harsh and gritty form of coke, sometimes changed to an unctuous body approaching graphite in aspect, yet different physically as well as in some of its chemical relations. Deposits of anthracite furnish carbon in yet another form. Besides these, the results of decomposition of what are known as organic compounds give quite a list of different forms of carbon, made either by the incomplete combustion of hydrocarbons, or by passing through red-hot tubes the vapors of hydrocarbons, chloride of carbon, sulphide of carbon, etc., or by the decompositions of such substances as carbonic acid, carbides of boron, of iron, of manganese, etc.

These various forms of carbon have certain chemical differences, more or less marked, which differences have attracted the attention of chemists, although no one has studied them with much care or success except M. Berthelot, their investigation being difficult on account of the want of proper methods. M. Berthelot obtained his results by taking advantage of the singularly slow oxidizing action of a mixture of nitric acid and chlorate of potash on carbon, first pointed out by M. B. C. Brodie, in 1860,* in experiments on graphite, by which he produced for the first time what is known as graphitic oxide. He operated by this means on very many specimens of carbon, from the diamond to lamp-black, embracing a large variety of artificially prepared carbons, and discovered certainly six or eight more or less distinct chemical characteristics of these different carbons.† The physical differences of some of them are well known; among these differences none is more remarkable than that of their specific heats. Other bodies known as elements, as silicon and boron, oxygen, etc., take upon themselves different conditions called allotropic conditions,‡—a term applied to the isomeric conditions of simple bodies; but carbon differs from these, not only in exhibiting a most wonderful variety of allotropic conditions, but also in the phenomena coming under the head of isomerism, polymerism, and metamerism; so much

* *Annalen der Chemie und Pharm.*, April, p. 6.

† The full detail of his researches is to be found in the *Annales de Chimie et de Physique*, IV, xix, 392, 1870 and xxx, 419, 1873.

‡ Notwithstanding the recent experiments of M. Weber, showing that under certain conditions, carbon, silicon, and boron are not exceptions to the law of Dulong and Petit, they still occupy a singular position in regard to specific heat.

so, that we are disposed to take this body away from the rank of a mere element, and call it a protean body that gives rise to substances of endless form and variety by combining with a very limited number of elements.

Additional interest attaches to carbon from the fact of its being regarded as belonging preëminently to the organic kingdom. In fact, some of the best observers and investigators assume that there is no such thing as mineral carbon among the rocks of our globe, and that wherever found, whether as diamond, graphite, or coal, it is a product derived from organic matter, in which it had first performed its part in the economy of nature.

A still more exciting interest has been felt in carbon since the new department of celestial chemistry has received the attention of scientists. And here we are not left for our knowledge of celestial carbon to the attenuated form of it which can be detected only by astronomical instruments; for masses of matter from other spheres reach our globe from time to time, bringing with them specimens of solid carbon for our investigation, and, at the same time, perplexing our minds with questions as to its mineral or organic origin, and as to the existence or not of life on other planets, and in other systems of planets.

Like the footprints of former life on the rock strata of our globe, these indications in what we call meteorites, however slight they may be, are not to be disregarded. While I do not wish to arrogate to myself any undue merit in the study of this subject, I must say that I believe that my methods published in 1855* set forth more prominently than it had been done before, the proper method of research for arriving at correct conclusions. It is clear that to attain positive results, the astronomer, physicist, mineralogist, and chemist must not run counter to one another in the use of the facts severally studied by them; and in all that I have done in this direction, it has been my effort to keep this in view.

In the present memoir, it is my object to develop new facts, and consider some points in connection with the carbon of meteorites.

1. *The Carbonaceous Meteorites.*

Certain well known meteorites, from among those whose fall has been observed, have been called, from their aspect, and from their containing a small amount of carbon, *carbonaceous* meteorites, although the small amount of carbon contained in them is not sufficient to account for their color. Perhaps the term *melanotic* meteorite would be a more appropriate one, to distinguish them from the stony and iron meteorites. There

* This Journal, II, xix, 153, 322.

are but four of them yet known, viz: that which fell at Alais in 1806, that at Kold-Bokeveldt in 1838, that at Kaba in 1857, and that at Orgueil in 1864. They contain, respectively, about 3, 2, 0·6, and 6 per cent of carbonaceous matter.

I would here remark that the Alais, Kold-Bokeveldt, and Orgueil are more closely allied to each other than to the Kaba meteorite. The predominating mineral constituents are about as follows:

	Alais, by Berz.	K-Bokt., by Harris.	Kaba, by Wöhler.	Orgueil, by Pisani.
Silica	31·22	30·80	34·24	26·08
Magnesia	22·21	22·20	22·39	17·00
Iron protoxide ..	29·03	29·94	26·20	29·60

If we now contrast these mineral constituents with those predominating in well-known meteoric stones, a most striking fact presents itself—one not commonly realized by those engaged in the study of these bodies. It is seen on comparing the above with the following tables:

	Chassigny.	Chateau Renard.	Harrison City.	Concord.	Danville.	Searsmont.
Silica	35·30	38·13	47·30	47·30	50·08	40·61
Magnesia	31·76	17·67	24·53	24·53	20·14	36·34
Iron protoxide ..	26·70	29·44	28·03	28·03	19·85	19·21

From these tabular statements, it will be seen that, deducting the small amount of carbon contained in the black meteorites, the mass of mineral matter constituting them is about the same, and corresponds thus with the so-called common type of meteoric stones; and hence the mineral matter to which these constituents belong must be the same in the two classes of meteorites, viz: olivines and pyroxenes, differing only in the more or less compact form of these minerals.

In the writings of some of the most astute observers of these bodies, we find little stress laid on these facts. Thus, M. Meunier, in a paper on the origin of meteorites, published in the *Cosmos* of December, 1869, expresses his amazement that I should speak of the circumscribed uniformity of the composition of meteorites as evidence of a circumscribed cosmical origin of these bodies, both with reference to the sphere or spheres whence they come, as well as their rock structure. He takes so opposite a view as to say (p. 9), "So far from the meteorites showing such a resemblance, we can establish between meteoric iron, olivine meteorites, aluminous meteorites, and carbonaceous meteorites, differences as great as between the most different terrestrial rocks." An assertion which would include all the ranges of rocks and sedimentary deposits from the basalt and granite to the cretaceous and tertiary deposits.

Let any one look at the above table, and say whether or not

he sees so vast a difference in the mineral constituents of the different meteorites there enumerated; and yet they represent the two extremes of these bodies so far as their external properties are concerned. It is well known that three or four minerals represent the great mass of the constituents of every meteorite in various proportions, viz: nickeliferous iron, olivine, pyroxene, and anorthite, especially the first three; and the purely iron meteorites must be recognized as magnified masses of the metallic particles to be found in every stony meteorite, not excepting even the carbonaceous meteorites.*

My object, however, in this paper is not to discuss at length the general internal resemblances of these bodies, as I may have occasion to do it more fully at another time. I wish simply to note, that black and pulverulent as are the carbonaceous meteorites, they are not removed by their mineral constituents from the so-called common meteorites. I now pass on to show that even in their carbonaceous constituent they are strongly linked even to the iron meteorites.

2. *Graphite carbon in the Iron Meteorites.*—Ever since the internal structure of this class of meteorites has been examined by sections through the center of these compact metallic masses, nodular concretions have been noted in their interior, the most common of which consist of *troilite*, a protosulphide of iron, and filling ovoidal cavities. Sometimes these troilite concretions have a thin coating of a lighter colored mineral known as *schreibersite*; and this last is also found alone in concretionary masses which are usually angular or lamellar.

Less frequent concretions than either of the above, and even more remarkable, consist of carbon of the character of graphite: these, like the troilite, usually fill irregular ovoidal cavities, and are more or less contaminated with the latter mineral.

The most important of the meteoric irons containing these nodules, that have come under my immediate observation, are the Toluca, the Cranbourne, the DeKalb, and the Sevier: the last two have received my special study, the latter furnishing much the larger part of the material in my hands.

Character of the graphite nodules.—These concretions differ more or less in appearance, while their general character is the same. In this communication I call special attention to a large nodule taken from the very center of the Sevier iron, the largest that has come under my observation, and perhaps the largest known. It was detached from the iron entire and perfect in every respect. Its greatest length is 60 mm.; its dimensions in

* At present, the Orgueil and Rhoda meteorites are the only two in which no positive evidence of the presence of nickeliferous iron has been traced; in the Orgueil, however, we find nearly three per cent of oxides, nickel and cobalt, and the Rhoda has not been very critically examined.

the other direction vary from 20 to 35 mm. The weight before it was cut was 92 grams. Its form is that of an irregular dumb-bell, flattened on one side, and slightly nodular on the surface. Its color is plumbago-black, except at small places on the surface, where there is a little bronze-colored troilite. Its texture is remarkably close and compact, and it is cut readily by the saw except when the tool encounters particles of enclosed troilite. Its structure and powder is not unlike that of the close-textured graphite of Borrowdale in Cumberland, England, and quite unlike the scaly graphite such as that from Ceylon, or that found in certain cast irons.

Examined from the circumference to the center this nodule presents the following appearances: About one-fifth of the circumference of the section is made up of troilite with a thickness of one millimeter. The remainder of the section has all the aspect of graphite, except in a few spots. In the nodule there is a small mass of troilite not unlike in form the entire nodule; it is 10 mm. long by about 5 mm. wide; it is not continuous from its circumference to its center, but the center portion is cut off completely from the exterior portion by a thin belt of graphite one-half to three-quarters of a millimeter in thickness. Again on other parts of the surface small particles of troilite are to be seen.

The specific gravity of this graphite is 2.26 mm., as determined on a piece in which no troilite was visible to the eye, and after it was immersed in water and placed under the receiver of an air pump to abstract the air from its pores.

Chemical character of the graphitic nodule.—When pulverized and heated in a short glass tube from 100° to 150° C., water is given off which is doubtless water absorbed from the air by the graphite. If heated a little higher and then brought close to the nose, a slight empyreumatic odor is apparent; if heated still higher, there is a slight odor of sulphuretted hydrogen. If heated in the open air the carbon is burnt with difficulty, showing its true graphitic nature.

Treatment of the graphite by ether.—Very pure and concentrated ether was added to two grams of material in powder and rubbed up in a porcelain mortar; then poured into a small beaker; a little more ether was added and the two allowed to remain together for 12 or 18 hours, the vessel being covered to prevent evaporation. The ether was then filtered off from the graphite which was finally washed with a little ether. The ether was allowed to evaporate slowly in the uncovered beaker placed where the temperature was about 33° C. After the ether had evaporated, long colorless acicular crystals covered the sides of the vessel, and some shorter ones were in the bottom. There were also some rhomboidal crystals and rounded particles. The

solid residue exhaled a peculiar odor of an aromatic character, somewhat alliaceous. The quantity of these crystals was small, not exceeding 15 milligrams from two grams of the graphite. Heated on a piece of platinum foil they fuse at about 120°C . Heated in a small tube closed at one end, they first melt and then volatilize, condensing in yellow drops that soon solidify leaving a carbonaceous residue. They are not soluble in alcohol, but very soluble in sulphide of carbon. Fuming nitric acid oxidizes the material, and gives, as one of the products, sulphuric acid. The quantity was too small to admit an ultimate analysis, but it was very evident that sulphur was the predominating constituent, the remainder being carbon and hydrogen. These three elements may be combined, forming a peculiar sulph-hydrocarbon, which in a previous note I called *celestialite*, or it may be sulphur containing a minute quantity of a hydrocarbon that gives the peculiar odor and determines the somewhat singular form of crystallization of the sulphur; for these acicular crystals may be only elongated rhombohedrons.

Be the compound what it may, it is a matter of chemical and astronomical interest that a solid graphite nodule thus encased in iron should contain a sulph-hydrocarbon, or free sulphur and a hydrocarbon.

The graphite powder, after treatment with ether, was then treated with bi-sulphide of carbon (which was re-distilled just before use) and after standing two or three hours was thrown on a filter; the filtrate was evaporated to dryness, and the residue was a yellow solid; in this instance, as in the last, the quantity was small. This, when heated in the open air on platinum foil to a red dull heat, first melts at about the temperature that sulphur melts, and finally the sulphur is burnt off, leaving a carbonaceous residue. When heated in a tube, it sublimes, leaving a black residue.

To all appearances this is the same substance, or mixture of substances, that was extracted by the ether, the ether not having exhausted the graphite in the first treatment.

The graphite nodules of the DeKalb and of the Cranbourne irons, on treatment with ether and sulphide of carbon, gave similar results. In the case of the Cranbourne graphite I had less than one hundred milligrams of the material to operate with, and I hardly hoped to obtain satisfactory results, but I did succeed, however, in obtaining such without the acicular crystals, for the whole residue was less than one milligram; but I had enough to recognize the peculiar odor, and also the minute quantity that could be scraped off the vessel in which the evaporation took place furnished the marked reaction by heat of volatilization in part and condensation of the same

with a carbon residue. The Cranborne graphite requires more trituration with the ether than that from the Sevier meteorite as it is more flaky on being rubbed up.

Further remarks about this peculiar substance will be made a little farther on, when I come to speak of the same compound as obtained from the black or carbonaceous meteorites.

Action of strong nitric acid on the graphite.—Strong nitric acid, poured upon the powdered graphite that had been treated with ether and bi-sulphide of carbon acted vigorously upon the sulphide of iron mixed with it, and after digestion for some time in the acid and washing thoroughly with water, there remained 55 p. c. of the original matter, which consisted of carbon. This burnt in air with great difficulty, but very easily in oxygen, leaving a residue of one per cent of ash.

The nitric acid solution was analyzed and found to contain

Sulphur.....	35.05	} Troillite.
Iron	62.21	
Cobalt	0.56	
Nickel.....	0.16	
Magnesia.....	0.30	
Silica	0.21	
	98.52	

It is a fact of some interest that in the sulphide of iron which occurs in meteoric irons (when these nodules are perfectly free from any adhering iron) the quantity of nickel and cobalt present is very minute, a most singular fact if we are to regard these nodules as the result of segregations from the mass of iron. And still further, while the nickel is very largely the predominant metal of the two in the iron, I have noted that the cobalt predominates over the nickel in the sulphide nodules; but I would not without further examination regard this as likely to be the rule in all cases.

Action of fuming nitric acid mixed with potash chlorate on the meteoric graphite.—The oxidation of graphite by this method is well known to chemists, it having been first pointed out, as I have stated, by Mr. Brodie in 1860, and subsequently by Berthelot in his elaborate memoirs published in the *Annales de Chimie et de Physique*, 4th series, volumes xix and xxx. The result is the formation of a substance which Brodie called graphitic acid and Berthelot graphitic oxide, although the compound invariably contains hydrogen as an essential element in its constitution. M. Berthelot made use of this reaction to study the different forms of carbon, finding that the results of the oxidation varied with the carbon from different sources, only those forms of carbon known as graphites proper furnishing the graphitic oxide. The same chemist studied this oxid-

izing action upon the graphite from the Cranbourne meteoric iron, and also upon the carbon from the Orgueil meteorite, and found that, of the two, only the graphite from the meteoric iron gave rise to the oxide.

The study of this subject I have pushed further, and have oxidized the graphites from the Sevier County and the De Kalb County meteorites, and have also re-examined that of the Cranbourne iron—having been very liberally furnished with a specimen by my friend, Prof. Maskelyne, of the British Museum. The carbonaceous matter from the Orgueil meteorite has also been subjected by me to the same reaction.

The details of conducting the process were identically those proposed by M. Berthelot in the memoirs already referred to, viz: To free the powdered graphite from sulphide of iron by first treating it with strong nitric acid, washing it thoroughly on a filter, drying it and mixing it with five times its weight of potash chlorate, then adding this mixture little by little to sufficient fuming nitric acid to moisten thoroughly the mass. In making the mixture, I place the nitric acid in a capsule and the latter in a little water with a piece of ice, thus avoiding any risk of explosion. The mixture, after standing a few hours is transferred to a ballon d'assais, and gently heated in a water bath at a temperature from 50° to 60° C. for several days. The result of this action upon the graphites of the Sevier County and DeKalb County meteoric irons was the formation of graphitic oxide, with all the characteristics of that furnished to Berthelot by the graphite from the Cranbourne iron, as well as to myself from this last graphite.

The conversion of the meteoric graphite into the oxide is more rapid than that of any terrestrial graphite with which I have experimented. The graphite soon changes from black to green, and finally, after two or three applications of the oxidizing agent, to a perfectly white substance. This, when filtered, washed, and dried under a bell glass with sulphuric acid, gives a yellow powder, somewhat adherent. If the oxidizing action of the nitric acid and potash chlorate be renewed several times on the same material, the oxide gradually diminishes in quantity, and if the process be stopped after the fourth or fifth treatment, the oxide is very gummy, adhering to the filter and preventing complete washing. When dried on the filter it adheres firmly, but can be detached by moistening the filter and rubbing off the paper with the finger, leaving tenacious flaky films.

The reaction and decomposition of the oxide obtained from the Sevier graphite is the same as that of the oxide from other sources.

My experiments on terrestrial graphites have been confined

to the Siberian, Cumberland, and Ceylon varieties; and they show that the graphite under consideration differs from them in being more readily converted into oxide, it requiring only one-fifth to one-third of the time; and if the operation be continued by frequently renewing the oxidizing agents, the oxide first formed gradually diminishes in quantity, being more thoroughly altered, like some of those forms of carbon ranked as not properly graphites.

In fact, it appears that the meteoric graphites, when tested by this process, occupy a place between graphites proper and ordinary carbon, but much nearer to the graphites.

After completing my examination of the carbon nodules of the irons, my aim was to see what general deductions could be made with reference to the relations this graphitic material bore to the carbon found in the black meteoric stones. The material to operate with is, however, very rare; but I had in my collection enough for all necessary comparisons, though needing much more in order to obtain the peculiar products in sufficient quantities for chemical analysis.

The Alais meteorite.

Two grams of this meteorite were pulverized finely and treated with boiling water, which dissolved out a small amount of matter; which substance has been studied by others and it is not my object to recur to here.

The powder was then dried and treated with pure ether, in the same manner as the graphite from the Sevier iron, and the ether allowed to evaporate slowly at a moderate temperature, when the sides of the vessel became covered with acicular crystals, mixed with a few rhomboidal crystals. The residue had a peculiar odor, similar to that of the ether extract from the graphite of the Sevier iron, which odor it nearly lost in the same way, after several days exposure to the air. The form and appearance of the crystals are the same as of those obtained from that graphite; and a portion of the crystals detached and heated in a small tube gave the same character or reaction.

These crystals have already been studied by Prof. Roscoe, of Manchester, as carefully as could be done with the minute quantity at his disposal. My examination is perfectly in accordance with his, and there is no doubt that this product and that from the graphite must be of the same nature.

We must not forget to mention that Prof. Wöhler was the first to call attention to the hydrocarbon in these black meteorites when examining the one which fell at Kaba.

Orgueil meteorite.

This meteorite is one of the most interesting of all the known carbonaceous meteorites. And there are one or

two points connected with it that do not appropriately belong to this paper, of which I will furnish a note before long. Through the liberality of Prof. Daubrée, and the Administration of the Garden of Plants, I have been furnished with the material on which my investigations have been made. This meteorite has, in most respects, been thoroughly examined by M. Cloez, and by M. Pisani, and their results given in the *Comptes Rendus* for 1864. The former chemist examined the carbonaceous matter as a whole, considering it to resemble humus; and this on drying at 110° gave him: Carbon 63.45, hydrogen 5.98, oxygen 30.75.

I have, as yet, done little toward the re-examination of this substance, which represents from four to six per cent of the entire meteorite, my examinations being made principally for those crystalline products, soluble in ether and bisulphide of carbon, of which I have found about one-half per cent in the meteorite.

The powdered meteorite was first treated with water and heated over a water-bath, and every thing soluble in that menstruum thoroughly washed out. The soluble portion, dried at 100° C., represents 8.65 per cent of the mass. After carefully drying the insoluble portion at 100° C., it was treated with ether in the same manner as the meteoric graphite. The ether was used in large excess, and allowed to remain for ten or twelve hours in contact with the material; the ether was filtered off, and the residue on the filter well washed with ether. The ethereal solution was evaporated slowly, when the same acicular crystals made their appearance as in the case of the graphite, and numerous rhomboidal crystals were deposited in the bottom of the beaker. These appeared to be identical with those from the graphite. The action of heat on these crystals is the same as on those from the Sevier graphite.

The powdered meteorite exhausted by the water and ether was next treated by the bisulphide of carbon, when an additional quantity of soluble matter was obtained. On evaporating the bisulphide of carbon, a yellow mass remained having the aspect of sulphur. This, when heated, gave evidence of being sulphur mixed with some carbon compound. And to all appearance it was just like the substance obtained by similar treatment of the meteoric graphite.

The crystals in the upper part of the vessel from which the ether was evaporated being detached by scraping the sides of the vessel with a horn spatula, some bisulphide of carbon was poured upon the portions remaining attached to the vessel by which it was dissolved. The bisulphide of carbon was subsequently evaporated, when a residue was left consisting of a yellow solid surrounded by a dark brown semi-solid mass in

minute quantity. This last is evidently a carbon combination not contaminated with sulphur, while the yellow mass is sulphur containing a small portion of the carbon compound.

I was enabled to obtain over 400 milligrams of these mixtures from about 50 grams of the meteorite, much the larger portion being sulphur. A few attempts were made to separate the sulphur from the carbon compound, but unsuccessfully; and I soon saw that by continuing my efforts, I should exhaust the small supply of material without reaching any useful result. So it was thought better to save what was left of the material as a specimen of it.

The other carbon meteorites I have not yet examined with regard to the points embraced in this report, but I hope to obtain sufficient material before long to allow of this being done, though I do not anticipate any different results from those that have been examined.

The nature of the hydrocarbon found in the meteoric graphite and carbonaceous meteorites.

That this substance belongs to the meteorites at the time of their fall, there can be no doubt; for in the carbonaceous meteorites there is nothing to enable us to account for its formation in the cabinets in which they have been placed after their fall. And in the case of the graphite nodules they were encased in the interior of an iron mass over twenty centimeters in diameter; and, furthermore, the powder operated with was taken from the interior of a compact nodule of graphite.

I have been strongly inclined to consider this as a hydrocarbon containing combined sulphur forming a sulph-hydrocarbon. In the absence of chemical evidence sustaining this view, I lay some stress on the peculiar odor of the ether extract, strengthened by a most singular property of the watery extract from the Orgueil meteorite, of which I will make a short statement, reserving for some future occasion any additional remarks.

If a small quantity of the powdered Orgueil meteorite, say two grams, be treated with water and heated for a short time over a water-bath, no peculiar odor will be observed, however carefully examined. Throw this on a filter and wash with water, then evaporate the filtrate to dryness over a water-bath, and during this time no odor will be observed. Allow the residue to cool, and still there is no odor. But now throw upon the residue a little water, say half to one cubic centimeter, move the capsule around to dissolve the mass, and then on bringing it near to the nose, a marked alliaceous odor will be perceived, sometimes so strong as to be disagreeable, reminding one of the odor of the oil of assafoetida. That it is produced

by a sulphur compound chemists will be apt to admit, perhaps a minute quantity of sulphur compound not unlike the sulphhydrate of ethylene $C^4H^6S^4$; and the needle-shaped crystals may not be far removed from the solid quintisulphide of ethylene, $C^4H^6S^5$, corresponding to sulphur 75.00, carbon 20.00, hydrogen 5.00. The crystals I scraped from the sides of the beaker—at the upper part—on which the ether solution of the Orgueil meteorite was evaporated to dryness, gave—sulphur 79.65, carbon 15.00, hydrogen 3.00.

In the above analysis the amount of sulphur is well determined; but the examination for carbon and hydrogen was made upon so small a quantity, that the results cannot be relied upon as very correct.

Roscoe burnt in dry oxygen .008 grams of the residue from the Alais meteorite, and obtained .010 grams of sulphurous acid, .008 grams of carbonic acid, and .003 grams of water, making sulphur 125 parts, carbon 54 parts, hydrogen 10.

As the above analysis was made with only eight milligrams, of course the results can be considered only as an approximation; but nevertheless, until we get better they must serve as our only guides.

I have not said anything about the gaseous carbon compounds found in meteorites, as these form a separate study from what is designed in this paper, and besides, Profs. Graham, Mallet, Wright, and others have already investigated their nature. Profs. Wright and Mallet are still engaged in this line of investigation.

Conclusions.

These then are some of the results of my experiments on the carbon of meteorites, and they are of great interest and importance. That we should find in the graphitic concretions from the interior of a solid mass of iron such substances as free sulphur and a hydrocarbon, simple, or combined with sulphur, having a marked odor, was certainly not to be expected, especially as we are almost forced to believe that the iron containing it must have been at some period in a state of fusion.*

The graphite nodules themselves are grand chemical and physical puzzles, as well as all the nodular concretions in meteoric irons; that they have resulted from a process of segregation is self-evident, but how marvelous the completeness of this segregation, for if we analyze the iron even within two or three millimeters of the concretions, only traces of the charac-

* In an article recently published by Dr. Mohr (*Annalen der Chem. und Pharm.*, Dec. 1875, page 257), he advances the theory that meteoric iron and meteoric stones have been formed by the agency of water; his arguments are interesting, but far from being sufficient to cover all the facts in connection with meteorites.

teristic constituents of the nodules are here found. Then again, in the case of the troilite concretions, this sulphide has been separated from the mass of iron, and a phosphide of iron and nickel has been concreting along with it; and yet, there seems to be so great an incompatibility between these two minerals that they could not commingle, but the phosphuret was thrust, as it were, to the exterior of the nodule, there to form a thin covering to the sulphide, like the skin of an orange over the internal pulp.

Again, the graphitic concretions bear no resemblance to the scaly graphite found in the slag of iron furnaces and between the crystals of cast iron, either in structure or appearance; the fractured surface is more like that of the Borrowdale graphite, but the oxidizing action of the nitric acid and potash chlorate on this last differs somewhat from the action on the meteoric graphite. Many and varied have been the hypotheses formed in my mind to account for the formation and accumulation of this graphite, but I must admit that I have been forced at last to abandon them all, as none covers all the facts of the case. In appearance this graphite is more like the amorphous carbon that is separated from cast iron, but the oxidizing action of nitric acid and chlorate of potash at once points out their great difference as shown by Berthelot's experiments.* And although it differs in appearance from the scaly graphite of iron, the oxidation of the two are very similar. I am more inclined to adopt the suggestion of Berthelot, that it may be formed by the reaction of bisulphide of carbon upon incandescent iron, as this reaction is known to give rise to an amorphous graphite analogous to the one under consideration, and its association with sulphide of iron would lend some support to this hypothesis; and still further the presence of free sulphur and a carbon compound, either a hydrocarbon, or sulph-hydrocarbon, points also in that direction for a solution.

It is very clear from the present accumulated knowledge of the geological occurrences of graphite that we must abandon all attempt to account for its formation by any one series of reactions on the interior of our globe; for it is to be found in basaltic rocks, in the older crystalline rocks, and through all the series of rocks up to the recent Tertiary formations; and when we add to this the laboratory experiments of Berthelot that I have so frequently quoted, this view of the subject is strengthened. But on this point I may have something more to say in a paper on the Ovifak iron, and the graphite in the basalt in which this iron is found.

The carbon from the black meteorites, as the Orgueil, Alais, etc., I consider as having a similar origin to that found in the

* *Annales de Chem. et de Physique*, Fourth Series, xix, 425.

irons; for I have proved that they both contain similar crystalline products soluble in ether and sulphide of carbon, and while the carbonaceous matter reacts differently when treated with nitric acid and potash chlorate, this may arise from the difference of conditions under which the reaction took place that gave rise to it.

That the carbonaceous matter in the black meteorites is to be regarded as a kind of humus arising from organized matter is contrary to all we know about humus. For if we examine the mineral constituents of these meteorites, we find them to be a granular mass, with particles more or less impalpable, composed essentially of olivine and pyroxene, a most unpromising soil for so luxuriant a growth of vegetation as must have occurred to produce so abundant a percentage of carbonaceous matter as that found in the Orgueil meteorite. The action of caustic potash upon it is different from the action of that alkali upon what is commonly called humus; (although we must bear in mind that humus is not a well-defined substance; it being commonly regarded as vegetable matter that has not undergone complete decomposition into water and carbon, but by imperfect oxidation was converted into a varied mixture of carbon and certain organic compounds rich in carbon, some of them soluble in caustic alkalies). After the powdered Orgueil meteorite has been exhausted by water, ether, and sulphide of carbon, caustic potash or soda dissolves but an exceedingly minute trace of the carbonaceous matter, and even that trace may be a little hydrocarbon not extracted from the mass by the ether and sulphide of carbon. If a portion of the same be dried at 110° C., and then heated in a closed tube, water will not be given off until the temperature is elevated considerably. If the temperature be further increased, only a very slight odor is apparent; and this is another marked difference between it and humus. If heated on platinum foil, the carbonaceous matter burns off very readily with little or no odor, leaving an abundant residue. According to my experiments this combustible matter amounts to about 4.5 per cent of the entire meteorite.

It is not at all improbable that the carbonaceous matter of the black meteorites approaches in character the so-called hydrated carbon first pointed out by M. Eggert, but so clearly defined by MM. Schutzenberger and Bourgeois in a communication made to the Chemical Society of Paris in April, 1875, which was obtained from white cast iron by dissolving away the iron. But it is a question in my mind whether the carbon combination thus obtained from white iron is to be properly considered a hydrated carbon; that is to say, whether we are to consider the H^2O as united to the carbon in the same way as it is to metallic oxides to form what are known as hydrated

oxides. If, however, it is to be considered as combined in a manner analogous to the H^2O , with ethyl to form alcohol, then there may be some plausibility in the hypothesis. For it will be remarked in referring to the actions of this hydrated carbon that it in no way resembles amorphous or ordinary carbon.

It is represented by MM. Schutzenberger and Bourgeois as follows: $C^{11}:3H^2O$ =carbon 70.95, hydrogen 3.23, oxygen 25.80 per cent.

According to M. Cloez, the carbonaceous matter of the Orgueil meteorite, after being dried at 110° , was found to be composed of carbon 63.45, hydrogen 5.98, oxygen 30.75; and when we consider that some of this hydrogen belongs to the hydrocarbon now known to exist in that meteorite, the remainder of the hydrogen will approach near the proportion required to form water with the oxygen; and the quantity of carbon that may exist as a hydrate will be slightly diminished.

Attempts were made to separate completely all the mineral matter from the carbon, but I have failed to do so, after using fluorhydric acid alone, and in conjunction with nitric acid, also fluoride of sodium and sulphuric acid with a small amount of water, then treating the residue with cold nitric acid. There is no difficulty in getting rid of a great part of it, but in every instance the carbonaceous matter has been altered, however carefully the temperature was managed.

When this matter thus obtained is heated in a closed tube, after being dried at $110^\circ C.$, it not only furnishes water at about $250^\circ C.$, but gives out a very strong odor somewhat like that produced from certain bituminous coals, at one point resembling the disagreeable odor of an ignited cigar of a very inferior quality of tobacco.*

Viewed in the light of these experimental researches, the most reasonable conclusion is that this carbonaceous matter is not in any proper sense either carbon or humus, but a carbon compound analogous to the one just referred to.

Future researches upon these solid compounds, resembling in appearance amorphous carbon, such as hydrographitic oxide, pyrographitic oxide, carbon-hydrate, and similar compounds that may yet be discovered, will doubtless throw some light on the true nature of the carbonaceous compound of the black meteorites. So far as our knowledge now extends, its formation and its origin are wrapped in as much obscurity as the origin of the bodies in which it is found.

What we do know is that this carbonaceous matter occurs with the same minerals, viz., olivine and pyroxene, which are the predominating constituent materials of all stony meteorites;

* This odor will be found to belong to the hydrated carbon from cast iron, when heated in the same way.

also with the nickeliferous iron found in both the stoney and metallic meteorites; and furthermore, that this carbonaceous matter contains curious crystalline products soluble in ether and sulphide of carbon, which last have been traced in the graphite nodules in the interior of the metallic meteorites. Moreover in these graphite nodules we have found magnesia, which is so uniformly a constituent of the minerals of the stoney meteorites.

So far then as our present knowledge goes, we know of celestial carbon in three conditions, viz: in the *gaseous form* as detected by the spectroscope in the attenuated matter of comets; in meteorites in the *solid form*, impalpable in its nature and diffused in small quantities through pulverulent masses of mineral matter that come to the earth from celestial regions; also in the *solid form, but compact and hard*, resembling terrestrial graphite, and this is imbedded in metallic matter that comes from regions in space. But while we speak of these as forms of carbon, I think we should be careful in associating it in our minds with the element carbon as we understand it in its pure state whether crystallized or amorphous, for I cannot reconcile the carbon vapor detected in comets as simply that known as pure carbon in the form of an elastic vapor, nor are we to circumscribe ourselves with the notion that this cosmical carbon has an organic origin.

The researches embraced in this communication, while in many respects of a novel character, are imperfect from their very nature, both from lack of material for a thorough and complete study, as well as from the present imperfect methods of operating upon a minute quantity of the most interesting of the substances obtained.

I have therefore detailed as carefully as I could all the results as they have developed themselves, hoping that future opportunities may be afforded for continuing them, when new celestial messengers of the carbonaceous type shall visit our globe.

the first of the year, the weather was very cold, and the snow lay deep upon the ground. The people were all dressed in heavy coats, and many of them wore hats of fur. The children were all in long dresses, and some of them wore bonnets. The men were all in long coats, and some of them wore breeches. The women were all in long dresses, and some of them wore bonnets. The children were all in long dresses, and some of them wore bonnets. The men were all in long coats, and some of them wore breeches. The women were all in long dresses, and some of them wore bonnets.

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